

# **Final Report**

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### ◇ Objective

In recent studies, Dr. L. Buck and Dr. R. Axel, who received Nobel Prize in Medicine in 2004, revealed the biological odor recognition process. According to their researches, the odor receptor receives odor molecules with recognizing molecular information. At length, the odor receptors recognize not whole structure of odor molecules but their common properties, called odotope. Therefore, molecular information can be regarded as the key to odor quantification, and it requires the sensor system with resolving the molecular information into their properties in order to recognize several kinds of odor flexibly. The aim of our research is to develop the odor sensor system which can resolve molecular information into the information of partial structures, so-called artificial olfactory epithelium. Furthermore, we attempt to quantify odor using molecular information.

### ◇ Status of Effort

In this study, an electrochemical cell was utilized for odor detection. There are an enormous number of odor receptors on the biological olfactory epithelium; therefore, the artificial olfactory epithelium also composes of multichannel reception sites. Furthermore, we developed the water membrane of the electrolyte solution (100 mM KCl and 60 % glycerin) to trap odor molecules flown in the air like nasal mucus. Fig 1 shows the artificial olfactory epithelium chip developed here.

In the measurement, we have done an electrochemical impedance measurement. In this study, hydroxyl group and aromatic ring were chosen as detection targets; then, we attempted to evaluate odors of aromatic alcohols quantitatively. Therefore, we have attempted to develop each channel with specificity to these partial structures. For the channel for hydroxyl group, we have added the ion-exchange resin into the water membrane to make the interaction between sensor surface and hydroxyl group active. For the channel for aromatic ring, we have formed a rough hydrophobic surface by competitive adsorption of benzene and 1 - octanethiol which can form self-assembled monolayer (SAM) [Figure 2]. This surface can be thought as the surface with affinity to hydrophobic partial structure like aromatic ring and with the roughness based on the shape of aromatic ring. Finally, we attempted to evaluate the change in odor induced by the concentration changes quantitatively using the technologies above.

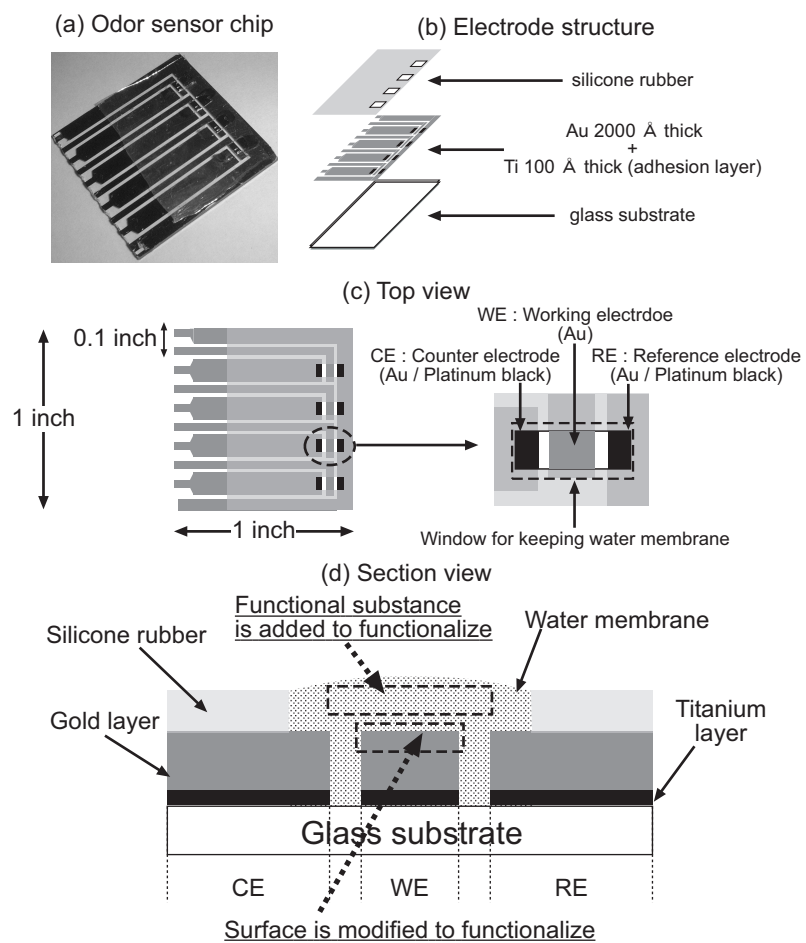


Figure 1: Artificial olfactory epithelium chip

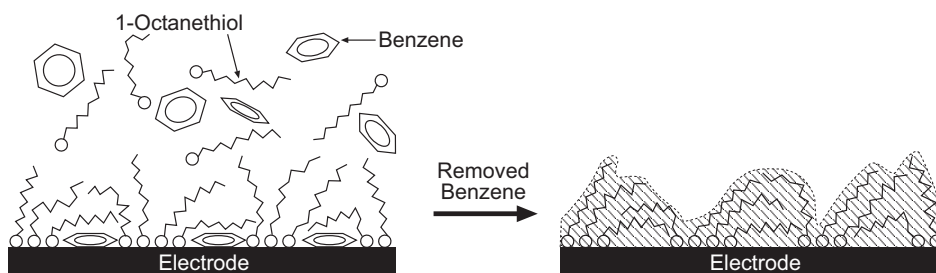


Figure 2: Channel for aromatic ring

### ◇ Abstract

The responses to odor molecules are represented by the change in the real part of electrode impedance  $\Delta R_e$ . We can evaluate the result by comparing the responses of 3 channels; "global" channel, "hydroxyl group" channel and "aromatic ring" channel. "Global" channel stands for the channel which is composed of no-addition to the water-membrane and no-modified surface, and it is regarded as a reference of the response of odor molecules. In this study, we measured ethanol which has hydroxyl group, benzene which has aromatic ring, and phenethyl alcohol which has both hydroxyl group and aromatic ring in its structure. Figure 3 shows their response with 3 channels.

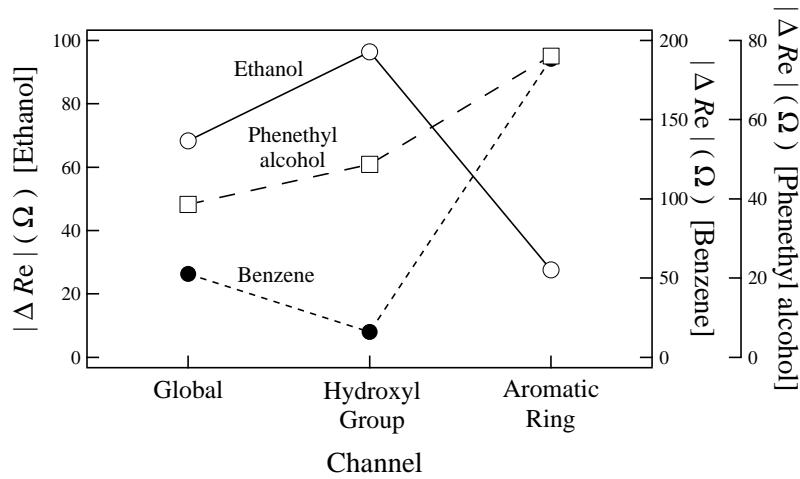


Figure 3: Response to ethanol and benzene with both channels

From Fig 3, the hydroxyl group channel responded to ethanol largely rather than with global channel, when it responded to benzene less than with global channel. P cellulose, included in the hydroxyl group, is cation-exchange resin, so pH of the water membrane is decreased since  $K^+$  ion is exchanged into  $H^+$  ion. This pH change might influence the detection of ethanol. On the other hand, the reason for the less response to benzene with hydroxyl group channel might be that the adsorption of benzene onto the surface was blocked by the interaction between benzene and P-cellulose. In this way, the addition of P cellulose to the water membrane can be operated

as the hydroxyl group channel.

On the other hand, the channel for aromatic ring responded to benzene well but not to ethanol so much. It might be because the electrode surface covered by the alkane chain of 1 - octanethiol is hydrophobic. Therefore, this hydrophobic surface can interact with hydrophobic partial structure such as aromatic ring, and it might block the adsorption of hydrophilic partial structure to the surface such as hydrophilic partial structure such as hydroxyl group. In this way, the rough hydrophobic surface can be operated as the aromatic ring channel.

From the result of phenethyl alcohol, both channels responded to it. It can be thought that each channel recognized not whole structures of odor molecules but the partial structures. In this way, the electrode surface could be functionalized by controlling the composition of water membrane and surface modification.

Using those results, we attempted to evaluate the odor of phenethyl alcohol quantitatively based on these partial structures. The odor evaluation is done by the intensities of hydroxyl group and aromatic ring. These intensities are calculated by the following relational expressions between response value and concentration.

$$\begin{aligned}\Delta R_e(\text{Ethanol}) &= a_{\text{alcohol}} * \log [\text{Ethanol}] + b_{\text{alcohol}} \\ \Delta R_e(\text{Benzene}) &= a_{\text{aroma}} * \log [\text{Benzene}] + b_{\text{aroma}}\end{aligned}$$

Then, the intensity of phenethyl alcohol was estimated using the equations above. In this study, we attempted to represent the change in the odor of phenethyl alcohol by concentration [shown in Fig 4].

From Fig 4, all results are plotted closer to axis of  $I_{\text{aroma}}$ ; therefore, this result indicates that the odor of phenethyl alcohol is dominated by aromatic ring rather than hydroxyl group. Furthermore, the results at lower concentration and at higher concentration are plotted closer to dashed line; however, the results at medium concentration are plotted far from the dashed line. Phenethyl alcohol at lower concentration smells like rose, but that at higher concentration smells like green grass or medicines. As the odor is also depended on the concentration, the results of Fig 4 stand for the change of the odor quality by concentration. In this way, we can indicate the possibility the odor can be quantified based on molecular information using the artificial olfactory epithelium.

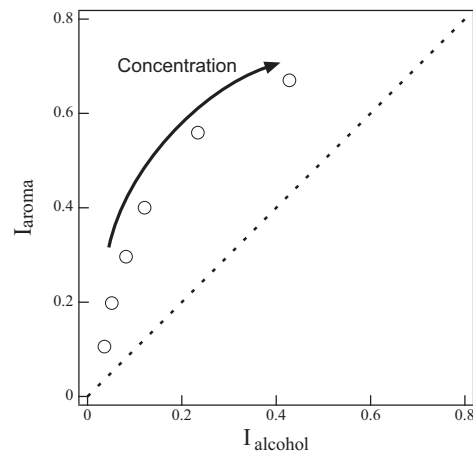


Figure 4: Odor quantification of phenethyl alcohol

#### ◇ Personnel Supported

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#### ◇ Publications

- Development of Artificial Olfactory Epithelium, R. Izumi, S. Etoh, K. Hayashi, K. Toko, *Proc. Asia-Pacific Conference of Transducers and Micro-Nano Technology-APCOT 2006 (June 25-28, 2006, Singapore, Singapore)*, 95-CSM-A0262, 2006.

◇ **Interactions**

(a) Participation/presentations

- Development of Artificial Olfactory Epithelium (Oral), R. Izumi, S. Etoh, K. Hayashi, K. Toko, *Asia-Pacific Conference of Transducers and Micro-Nano Technology-APCOT 2006 (June 25-28, 2006, Singapore, Singapore)*, 2006.

(b) Utilization of our knowledge

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◇ **New**

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